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Article

Application of Decision-Making Trial Evaluation and Analytical Network Process to Fruit Bag in Service Design

Hsin-Hung Lin [1,2,*], and Jui-Jung Wei [3]

[1] Department of Creative Product Design, Asia University, Taichung 41354, Taiwan
[2] Department of Medical Research, China Medical University Hospital, China Medical University, Taichung 406040, Taiwan
[3] Department of Business Administration Asia UniversityTaichung, Taiwan; 110231004@live.asia.edu.tw
* Correspondence: hhlin@asia.edu.tw

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Abstract: We explored the causal relationship and importance of evaluation factors to purchasing decisions taking the service design of Kiwi bag design for consumers as the research object and using decision-making trial evaluation (DEMATEL). The three most important key evaluation factors before purchasing Kiwi bags were found to be “beauty”, “operability” and “durability”. “Beauty” was the influencing factor while “operability” was the main factor. It is recommended to consider these factors to design bags and to investigate possible directions for the evaluation. In the modeling process, it is necessary to quantitatively evaluate simple factors chosen from complex interacting factors and use the results to determine future designs.

Keywords: Modular design, Product family, Interpretive structural model, Product design

1. Introduction

Tazki and Amagsa (1997) pointed out that when people learn complex and disagreeable questions or behavioral problem analysis and need assessments, they usually use their intuition and experience to judge. Therefore, in ideal planning and efficient methods, the impact of different evaluation indicators of decision-making trial evaluation (DEMATEL) needs to be considered. The relationship between the DEMATEL test criteria and the relative weights of the criteria can be studied using an analytical network process (ANP). The analysis includes internal and external customer satisfaction as a comprehensive reference. In the past, many scholars believed that consumers' purchase intention determined the consumer's cognitive value of the product. Scholars proposed cognitive price, quality, and value models to explain the formation of consumers' purchase intention and carried out relevant empirical research. (Hsiao et al., 2013). According to the research, consumers are often influenced by aesthetics when purchasing products as aesthetics is the easiest way to identify the product (Hsiao and Liu, 2005), and aesthetic awareness affects the consumer's purchasing habits as an unquestionable factor. In terms of aesthetics, a general model of brand loyalty is established with proposed factors affecting brand loyalty such as product characteristics, marketing strategy, and market structure. Snyder and Fromkin (1997) stated the theory of uniqueness as “when the uniqueness of the self-concept is threatened, the individual's different needs from others will be provoked by certain motives.”

Tseng employed the theory of mixed fuzzy sets and ANP. He checked two types of structures to investigate the problems and standards in the management of the green supply chain (Tseng et al., 2014). Huang used DEMATEL and ANP to investigate the factors for the development of wind power and the community’s understanding of safety, quality, environment, and ecology. He gathered relative weights of the related standards which served as a reference for enterprises and governments (Yeh and Huang, 2014). Hsu (2012) adopted a mixed method of DEMATEL for the simplification and visualization of the relations between strategic decisions. Chang used DEMATEL to analyze and predict supply in the electronics industry and assisted enterprises precisely to predict supplier’s performance including the key indicator of cargo consignation. His approach affected the selection of suppliers. Although it did not comply with the expectation of the supplier of the highest value, it effectively assisted enterprises in selecting the optimal supply-chain management to manage suppliers (Chang, 2011).

Based on the concept of modularization, diversified design ideas, and various suggestions, product development was conducted against different demands, and the manufacturing costs were reduced by sharing components between products. Based on a concept proposed by Hsiao et al. (2003) of sharing parts and components between product assemblies, the relations between product components was investigated by the sequencing model proposed as well.

Therefore, we considered the key factors affecting consumers' choice of bags to effectively evaluate development plans. Based on the general consumer purchase behavior, the evaluation factors were determined for making decisions on the purchase of exotic fruit bags. The key factors for decision-making were explored to make consumers purchase Kiwi bags by establishing an evaluation model of causality. The research findings suggested relevant product marketing strategies and market development planning recommendations.

2. Theoretical Framework

In this study, products were categorized to determine the relationship between them and obtain a matrix of relationships between design services between markets. The relationship matrix was used to determine the optimal product design. The flow chart of the research process is shown in Fig. 1. First, the component methods were used to calculate component weights and then execute the DEMATEL method to construct the product's relationship matrix. Finally, market segmentation using the cluster sample survey was performed, and the supermatrix was built with the ANP method based on the weight of each element. The implementation procedure is as follows:

(1) The impact matrix was obtained through the DEMATEL standard;
(2) A relationship matrix was constructed;
(3) The matrix was exported;
(4) An element distribution map was drawn;
(5) Cluster samples were surveyed;
(6) a supermatrix set was established;
(7) The weight of the element was obtained;
(8) After establishing clusters and markets through ANP, the design with the best weight was determined.

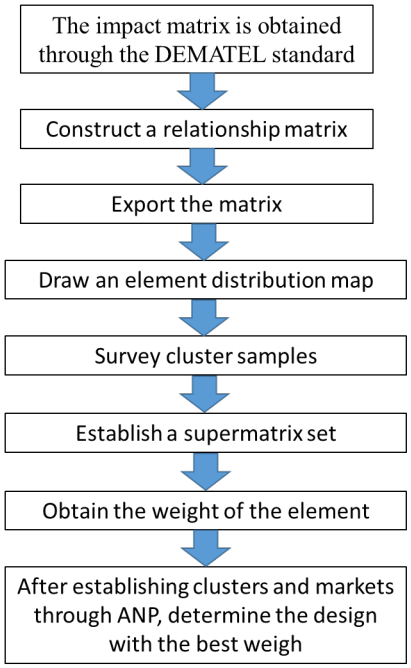

Fig. 1. Framework of proposed method in this study.

3. Development Process for Research Model

We used the DEMATEL method for data analysis because DEMATEL was used to analyze the relationship between the problems to find the primary and secondary solutions and construct the causal relationship between the evaluation factors of consumers' decision-making on purchasing Kiwi bags. We also carried out in-depth interviews and a questionnaire survey to find out the respondents' views on the relevant topics to collect more detailed information. Based on the literature review, factors affecting consumer decision-making behavior were explored and summarized. As a result, three main aspects were determined: professional consumption, purchase decision-making processes, and evaluation criteria of consumers. Professional consumption was affected by three factors: "unique demand", "conspicuous consumption" and "materialism". The purchase decision process was

affected by “pre-purchase behavior” and “purchase”. Evaluation criteria were affected by “popularity”, “product” and “brand” as post-behavior.

3.1. DEMATEL

The DEMATEL method is used to check whether there is an interaction relationship or self-reward between factors and construct a network relationship diagram. Tzeng et al. (2007) pointed out that DEMATEL provided a feasible solution for specific problems through a hierarchical structure. Relevant articles on the DEMATEL method have been published as this method was used to effectively understand complex causal relationships. By examining the degree of influence between factors, the causal relationship between the overall factors and the intensity of influence was further calculated. A network relationship structure model was established to graphically examine the complex influences between factors. DEMATEL consists of five steps (Wang et al., 2013):

- Step 1: Average impact matrix

  Criteria are used in a pairwise judgment to assess each respondent's perception of the extent of the impact between the indicators. Respondents are asked about the direct impact of the indicator on an impact scale of 0, 1, 2, 3 to 4 which pertain to “completely no impact (0)”, “slight impact (1)”, “general impact (2)”, “high impact (3)”, and “significant impact (4)”. Respondents’ answers are used to obtain a $n \times n$ direct impact matrix $\boldsymbol{A} = [a_{ij}]_{n\times n}$.

- Step 2: Normalization of direct influence matrix

  The direct influence matrix is normalized using Eqs. (1) and (2), and the normalized influence matrix $\boldsymbol{D} = [d_{ij}]_{n\times n}$ is obtained. The matrix diagonal is 0.

$$\boldsymbol{D} = k\boldsymbol{A} \tag{1}$$

$$k = \min\left\{1/\max_i \sum_{j=1}^{n} a_{ij}, 1/\max_j \sum_{i=1}^{n} a_{ij}\right\}, \quad i, j \in \{1, 2, ..., n\} \tag{2}$$

- Step 3: Calculation of total impact relationship matrix

  After obtaining the normalized direct influence matrix, the total influence matrix T of the constructed network relationship is assessed by Eq. (4), where I is an identity matrix.

$$\boldsymbol{T} = \boldsymbol{D} + \boldsymbol{D}^2 + \boldsymbol{D}^3 + ... + \boldsymbol{D}^k = \boldsymbol{D}(\boldsymbol{I} + \boldsymbol{D} + \boldsymbol{D}^2 + ... + \boldsymbol{D}^{k-1})\ [(\boldsymbol{I} - \boldsymbol{D})(\boldsymbol{I} - \boldsymbol{D})^{-1}]$$

$$= \boldsymbol{D}(\boldsymbol{I} - \boldsymbol{D}^k)(\boldsymbol{I} - \boldsymbol{D})^{-1}$$

$$\boldsymbol{T} = \boldsymbol{D}(\boldsymbol{I} - \boldsymbol{D})^{-1},$$

  when $k \to \infty$,

$$\boldsymbol{D}^k = [0]_{n\times n} \tag{3}$$

  when $\boldsymbol{D} = [d_{ij}]_{n\times n}$, $0 \le d_{ij} \le 1$, $0 < \sum_{j=1}^{n} d_{ij} \le 1$, $0 < \sum_{i=1}^{n} d_{ij} \le 1$.

- Step 4: Analysis of results

  The summation along columns ($\sum_{j=1}^{n} t_{ij} = t_i$) and that along rows ($\sum_{i=1}^{n} t_{ij} = t_j$) of the matrix are used to establish influence index vectors $\boldsymbol{r} = (r_1, ..., r_i, ..., r_n)'$ and $\boldsymbol{c} = (c_1, ..., c_j, ..., c_n)'$ which are defined by Eqs. (4) and (5).

$$\boldsymbol{T} = [t_{ij}]_{n\times n}, \quad i, j = 1, 2, ..., n$$

$$\boldsymbol{r} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} = [t_{i\cdot}]_{n\times 1} = (r_1, ..., r_i, ..., r_n)' \tag{4}$$

$$\boldsymbol{c} = \left[\sum_{i=1}^{n} t_{ij}\right]'_{1\times n} = [t_{\cdot j}]_{n\times 1} = (c_1,...,c_j,...,c_n)' \tag{5}$$

where vector r and vector c represent the summation of rows or columns of the overall influence matrix $\boldsymbol{T} = [t_{ij}]_{n\times n}$ respectively.

- Step 5: DEMATEL network relation chart

  With the known degree of influence, the difference in the strength of a measure influences each other. The value reveals how randomly all questions belong to one question. When its value is positive, the metric is close to the cause group. When its value is negative, the index is close to the result group.

3.2. ANP

Saaty (1980) proposed the method of ANP based on an analytical hierarchical process (AHP). He added a feedback mechanism to the conventional linear AHP and presented the data in a network. By considering the interdependency between various factors, a strategic decision can be made systematically (Saaty, 1996). This approach also provides a systematic method to identify the targets for an organization and its priorities. Karsak et al. (2002) proposed a combined analytic network process that had quality functions applied to resource distributions. During the product design process, any limited resources needed to be properly distributed to every workstation (Yu, 2002; Yu and Shing, 2013). The application of AHP to the solution of complicated problems comprises the following six steps:

- Step 1: Defining a problem. All factors that affect the problem are included in the system of the problem. A planning group must be set up to define the scope of the problem;
- Step 2: Constructing a hierarchical structure. The members of the planning group brainstorm to find out the criteria and sub-criteria for assessing the problem, the nature of alternatives, and alternative solutions;
- Step 3: Designing the questionnaire and conducting a survey. Using a higher-level element as the evaluation criterion, each element is compared with the other. Therefore, it is necessary to design a questionnaire for each pairwise comparison. Questionnaires are filled out on a scale of 1 to 9 by decision-makers or decision-making team members. The problem of each pairwise comparison must be clearly described;
- Step 4: Checking the consistency of the levels. A pairwise comparison matrix is established based on the survey results to obtain the eigenvalues and eigenvectors of each pairwise comparison matrix to check the consistency of the matrix;
- Step 5: Choosing a plan. If the overall level is consistent, the priority vector of the alternative plan is determined. If there is only one decision maker, only the comprehensive evaluation point (priority) of the alternative is determined. If there are multiple decision-makers, the comprehensive evaluation point of each decision-makers alternative is calculated separately;
- Finally, the weighted average method (such as the geometric average method) is used to determine the weighted comprehensive evaluation points and the priority of the alternatives. Similar to AHP, ANP also uses pairwise comparison to obtain network relationships on a scale of 1 to 9. ANP allows inner dependence within a cluster and outer dependence between clusters. It provides a complete framework that includes the connection between each cluster and element.

  ANP is divided into two parts as follows.

(1) The first part is “control hierarchy” which is used to understand the network relationship between criteria and sub-criteria. It affects the internal relationships between systems;
(2) The second part is the network relationship between elements and clusters. From the network relationship, the correlation between criteria is determined, and the limiting influence between each control criterion is calculated to form a supermatrix (Eq. (6)).

$$W_i = \left(\prod_{j=1}^{m} a_{ij}\right)^{1/m} \Bigg/ \sum_{i=1}^{m}\left(\prod_{j=1}^{m} a_{ij}\right)^{1/m} \quad ; \quad i, j = 1, 2, 3, ..., m \tag{6}$$

where m is the number of decision factors.

The pairwise comparison matrix A by the obtained eigenvector W_i. To obtain a new vector, the average fold between λ_{max} is calculated using Eqs. (7) and (8).

$$\begin{bmatrix} 1 & a_{12} & \cdots & a_{1m} \\ a_{21} & 1 & \cdots & a_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \cdots & 1 \end{bmatrix} \begin{bmatrix} W_1 \\ W_2 \\ \vdots \\ W_m \end{bmatrix} = \begin{bmatrix} W_1^{'} \\ W_2^{'} \\ \vdots \\ W_m^{'} \end{bmatrix} \tag{7}$$

$$\lambda_{\max} = \frac{1}{m}\left(\frac{W_1'}{W_1} + \frac{W_2'}{W_2} + \cdots + \frac{W_m'}{W_m}\right) \tag{8}$$

4. Module Concept

Fig. 2 shows different Kiwi bag designs. The designs were used to verify the feasibility of DEMATEL.

Fig. 2. Kiwi bag designs.

We used DEMATEL to construct the causal relationship between the decision-making and evaluation factors of purchasing Kiwi bags. We also carried out in-depth interviews and a questionnaire survey to explore the respondents' views. 32 respondents replied to the questionnaire survey, and 26 submitted validated responses. All respondents were fruit farmers. Table 1 shows the five aspects and their mutual influences, which were in line with other aspects. The degree of the influence of display was the most influential on comfort, and delivery was the least influential in all aspects. Removing values from the total impact relationship matrix (T) represented a more significant causal relationship with a set threshold, which was the arithmetic mean of the values in (T).

Table 1. Overall influence relation matrix of criteria.

T	Operability	Practicability	Aesthetics	Safety	Productivity	Functionality	Deliverability	Total	Rank
Operability	1.030	1.087	1.046	1.221	0.975	0.755	0.469	6.583	5
Deliverability	1.184	0.971	1.098	1.185	1.018	0.743	0.475	6.673	4
Aesthetics	1.380	1.304	1.090	1.404	1.091	0.901	0.564	7.732	1
Safety	1.267	1.150	1.109	1.089	0.984	0.785	0.499	6.883	3
Productivity	1.093	1.026	0.968	1.093	0.773	0.695	0.449	6.097	7
Practicability	1.313	1.199	1.217	1.357	1.047	0.742	0.545	7.419	2
Functionality	1.132	1.083	1.076	1.166	0.915	0.765	0.415	6.552	6
Total	8.398	7.819	7.603	8.515	6.802	5.386	3.416	0.978	-
Rank	2	3	4	1	5	6	7	-	-

Any value greater than or equal to the threshold value was plotted on the coordinate graph in seven criteria as shown in Table 2. To make the causal relationship between the criteria revealed more easily, it was assumed that only T had greater values than the threshold value. This simplified the total impact of the evaluation and analysis. Fig. 3 shows the plot of $(D + R)$ and $(D - R)$ on the x and y axes on which the seven criteria were plotted. The plot shows significant influential relationships between all criteria. Compared with other criteria, conformity to production and aesthetics were more important as influential criteria. Productivity and delivery had the least impact on other criteria. Operability, practicality, aesthetics, safety, and functionality represented the interrelationship between the indicators, which means that they affected each other.

Table 2. Averages values in DEMATEL analysis.

Deliverability	**Operability**	**Practicability**	**Aesthetics**	**Safety**	**Productivity**	**Functionality**	**Deliverability**
Operability	1.030	1.087	1.046	1.221	0.000	0.000	0.000
Deliverability	1.184	0.000	1.098	1.185	1.018	0.000	0.000
Aesthetics	1.380	1.304	1.090	1.404	1.091	0.000	0.000
Safety	1.267	1.150	1.109	1.089	0.984	0.000	0.000
Productivity	1.093	1.026	0.000	1.093	0.000	0.000	0.000
Practicability	1.313	1.199	1.217	1.357	1.047	0.000	0.000
Functionality	1.132	1.083	1.076	1.166	0.000	0.000	0.000
	Operability	**Practicability**	**Aesthetics**	**Safety**	**Productivity**	**Functionality**	**Deliverability**
D + R	14.981	14.492	15.335	15.398	12.898	12.806	9.969
D − R	−1.814	−1.146	0.129	−1.632	−0.705	2.033	3.136

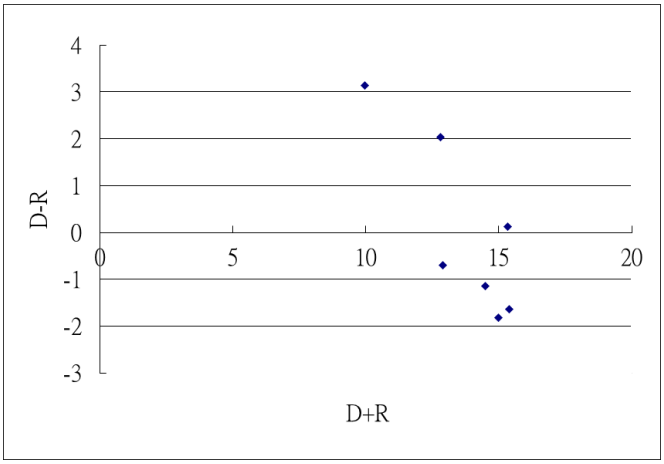

Fig. 3. $(D + R)$ and $(D - R)$ distribution in DEMATEL plot.

4.1. Establish Evaluation Criteria

The standard criteria were evaluated using the data from the questionnaire survey. The input values were calculated by DEMATEL, and the matrix of the average opinion of the professionals was obtained as shown in Table 3. After obtaining the normalized direct relation matrix, the overall effect was shown in the standard T to determine the criteria. The average of all values in Table 5 was 0.79, and in the relationship matrix, the standard overall influences were excluded when they had a value below 0.79. There were interactions between five components. Practicality and aesthetic standards were the most influential and most affected criteria. Manufacturability and deliverability were the least influential and were impacted by other criteria. Therefore, operability, usability, aesthetics, security, and functionality were more susceptible than other criteria, being classified in the resulting cluster. The interaction between the indices is shown in Table 4.

The five parameters considered for the Kiwi bag design were described as follows.

(1) Function was provided during the application process. The main considerations were energy savings or other special features.
(2) Practicality was for the use of the product is suitable for the individual. The main considerations were ease of use, ease of storage, weight, and size.
(3) Operability: In addition to the necessary function, consumers considered the bag as an accessory with certain functionality

such as a manual adjustment.

(4) Aesthetics: The overall aesthetics of the product's appearance including shape, material, and color were considered to affect the beauty, style, and texture of the bag.

(5) Safety was important in using the bag. The main considerations were ruggedness and durability.

Through the calculation in ANP, it was possible to develop and redistribute each requirement. Components with different weight distributions were used. The weights with smaller differences were combined to analyze the distribution of the design values. The optimized ANP weights were calculated as shown in Table 3.

Table 3. ANP weights.

Image	Considerations	Weights		Weights
	Operability	0.154		0.185
	Practicability	0.060		0.249
	Aesthetics	0.494		0.313
	Safety	0.043		0.028
	Productivity	0.250		0.225
	Functionality	0.167		0.174
	Practicability	0.077		0.149
	Operability	0.477		0.504
	Aesthetics	0.058		0.042
	Safety	0.222		0.131
	Functionality	0.192		0.135
	Practicability	0.104		0.219
	Operability	0.154		0.324
	Aesthetics	0.303		0.037
	Safety	0.247		0.286
	Functionality	0.191		0.204
	Practicability	0.230		0.238
	Operability	0.208		0.235
	Aesthetics	0.105		0.183
	Safety	0.266		0.139

Table 4. DEMATEL weights of different Kiwi bag designs.

Bags				
Weight	0.781	0.871	0.978	0.952
Bags				
Weight	0.867	0.921	0.872	0.812

5. Conclusions

Using DEMATEL, we obtained and evaluated criteria in the design process of Kiwi bags. The method was more appropriate for choosing product designs because in the DEMATEL method, weaker relationships between criteria were eliminated. It was found that the criteria in DEMATEL were used to determine connectivity and process ANP between the criteria. Using ANP, complex designs could be found to pass a conformance test. Pairwise comparisons objectively demonstrated the importance of the criteria and their applications. The product design method was verified by respondents and was used to define the Kiwi bag design which was preferred by consumers.

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